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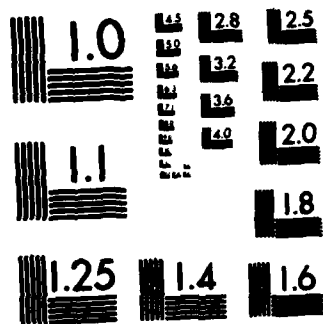   WASHINGTON DC   F C LIN ET AL. 23 MAR 83 NRL-8681
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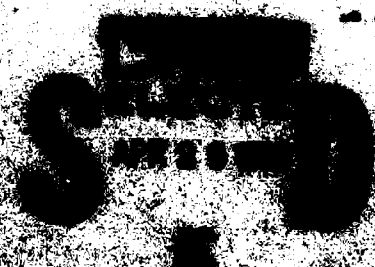MICROCOPY RESOLUTION TEST CHART
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Parameter Estimation and Target Detection in a Distributed Clutter Environment

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A requirement for the simultaneous measurement of range and velocity of a radar target (parameter estimation) can be satisfied by using a waveform with a thumbtack-type ambiguity diagram and implementing a bank of matched filters in the absence of distributed clutter. It is demonstrated here that this technique cannot be applied in a distributed-clutter environment, because it provides no subclutter visibility for detecting targets. To eliminate nonmoving clutter, a moving-target-indicator (MTI) delay-line canceler must be used on all doppler-filter outputs.

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20. ABSTRACT *(Continued)*

This scheme suffers from blind-speed problems and prevents parameter estimation with a single pulse . To date no known technique based on a single pulse can achieve parameter estimation in distributed clutter. It is shown that in such an environment, with two or more pulses an MTI system using equal and oppositely range-doppler-coupled waveforms not only simplifies the required hardware with no blind-speed problem but also provides subclutter visibility and accomplishes accurate parameter estimation simultaneously.

CONTENTS

PARAMETER ESTIMATION AND TARGET DETECTION IN A DISTRIBUTED-CLUTTER ENVIRONMENT

INTRODUCTION

The three basic purposes of a radar are target detection, target resolution, and parameter estimation. For a single target, the tasks of target detection and parameter estimation are in principle quite simple if sufficient signal energy guarantees precise measurements of target range, velocity, and other parameters. The real test of a radar is its ability to resolve the desired targets from clutter and to detect targets and estimate parameters simultaneously in the presence of clutter. The mutual interference caused by other scatterers will in general make target resolution difficult.

Any response of a practical receiver always has a main peak surrounded by several time sidelobes or slowly decreasing tails. In an environment with distributed clutter or multiple targets, the sum of all these low-level responses may build up to a level sufficiently high so as to mask even relatively strong targets. It has been stated [1] that parameter estimation is one of the fundamental applications of large time-bandwidth signals. It is generally believed that the optimum implementation for parameter estimation is a bank of matched filters obtained by doppler-correcting a nonrange-doppler-coupled pulse compressor [1,2]. Although this is true in the absence of clutter, this report demonstrates that the doppler filter bank described above cannot provide subclutter visibility in a distributed-clutter environment. In such an environment the clutter will mask the targets, preventing both target detection and parameter estimation.

The implementation of a moving-target indicator (MTI) at each output port of a doppler-steered pulse compressor can eliminate the excess clutter (to be defined later), but the radar will require at least two transmitted pulses and will operate with blind-speed limitations. As will be described, for two or more pulses when the proper waveforms are employed, radar performance can be improved significantly in distributed nonmoving clutter. Both subclutter visibility and accurate parameter estimation can be achieved at the same time.

CODES WITH A THUMBTACK-TYPE AMBIGUITY FUNCTION

It has been stated [1] that the simultaneous measurement of the range and velocity of a radar target (parameter estimation) is accomplished with minimum error when the waveform employed does not range-doppler couple. The thumbtack-type ambiguity function, with a narrow spike surrounded by a uniformly low pedestal, is usually considered for parameter-estimation applications.

The aperiodic maximum-length binary shift-register codes have an ambiguity function which approximates a thumbtack type of characteristic. These codes are derived from recurrence formulas which are suitable for shift-register implementation [3]. The coefficients of the primitive polynomial of degree n specify the stages used in the feedback path. Codes of length 2^n-1 are generated by sensing predetermined stages of the n-bit shift register and summing modulo 2, with the result applied to the input of the shift register. When code generation starts, different initial conditions with binary elements in the shift register will yield cyclic permutation of the code. Among these permutations, there are codes with either the lowest peak sidelobes or the lowest RMS sidelobes. In addition to the maximum-length binary codes, Barker codes also have thumbtack-type ambiguity functions. However, no known Barker code exists with length greater than 13.

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In the matched-filter-bank implementation for parameter estimation, each filter in the bank is tuned to a different center frequency (doppler-steered pulse compressor). For a maximum-len$_{b}$:h-sequence and Barker-coded waveforms, a doppler shift of m/τ (m = integer, τ = code duration) reduces all the matched-filter peak responses to the sidelobe level, except the F_m filter, which is the filter matched to the doppler shift of the received signal. Under the latter condition a peak response is obtained; its location indicates the true range, and the filter number identifies the target velocity. The responses of the $F_0, F_1, F_2,$ and F_3 doppler filters with a zero-doppler target are shown in Fig. 1 for one of the 127-element-maximum-length pseudorandom binary waveforms and in Fig. 2 for the 13-element Barker code. The responses of the $F_0, F_1, F_2,$ and F_3 filters with an F_2-doppler target (with a doppler shift of $2/\tau$) are shown in Fig. 3 for the same maximum-length binary code as in Fig. 1.
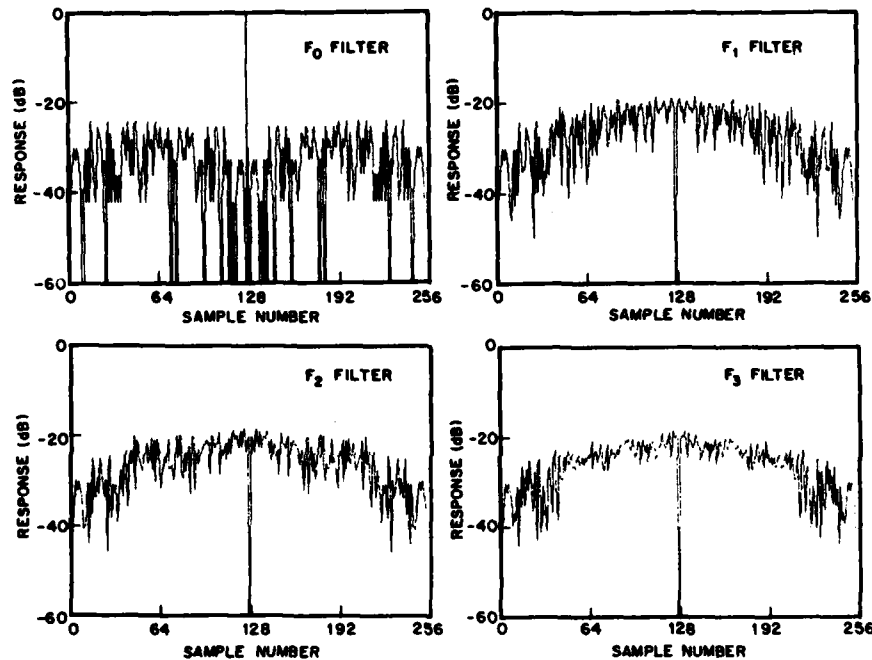

Fig. 1 — Responses of the doppler filters with a zero-doppler target for a
127-element-maximum-length binary code: $(217_8, 127)$

DISTRIBUTED-NONMOVING-CLUTTER ENVIRONMENT

In a distributed-clutter environment, the range extent of the clutter is assumed to be much greater than the transmitted pulse duration. For the distributed clutter, it is assumed that the I and Q components of clutter cells are independently Gaussian distributed with zero mean and equal variance. Therefore, the amplitudes of clutter cells are Rayleigh distributed, and the phases are uniformly distributed. The responses for one realization of the nonmoving-distributed-clutter model were obtained at outputs of doppler-steered pulse compressors when several maximum-length binary-sequence and Barker codes were adopted for input waveforms. The mean-squared output clutter powers from the doppler-steered pulse compressors employing these waveforms are listed in Table 1 for the $F_0, F_1, F_2,$ and F_3 filters. The results consistently show that the clutter power effectively comes through all the doppler-steered passbands on the range-time sidelobes with nearly as much power as that at the matchpoint in the zero-frequency passband. This integrated time-sidelobe power has been called excess clutter and gives rise to what has been called processing loss or degradation [4]. Work to date has revealed that no codes with a thumbtack-type ambiguity function in the implementation of doppler-corrected pulse compressors will provide subclutter visibility in the presence of nonmoving distributed clutter.
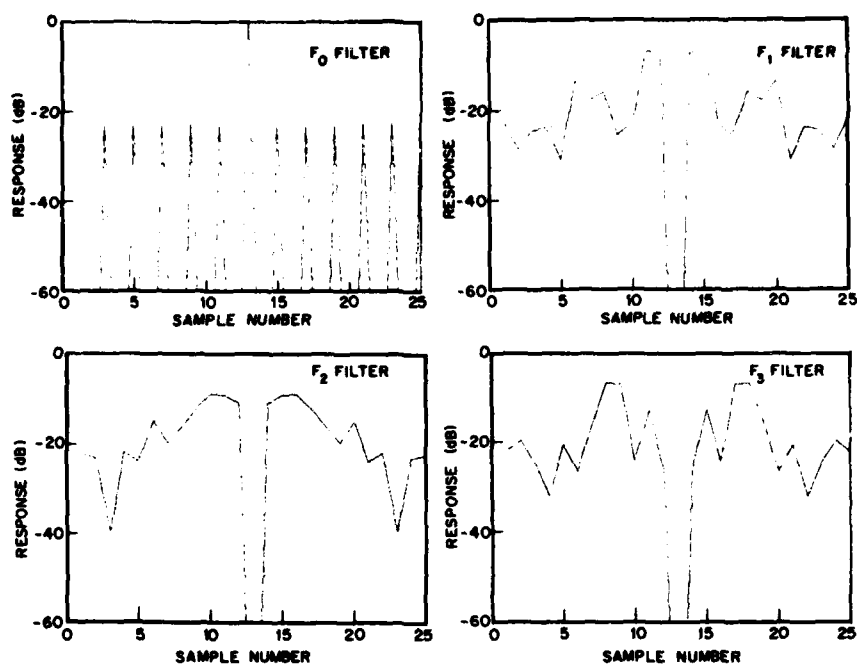
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Fig. 2 — Responses of the doppler filters with a zero-doppler target for the 13-element Barker code
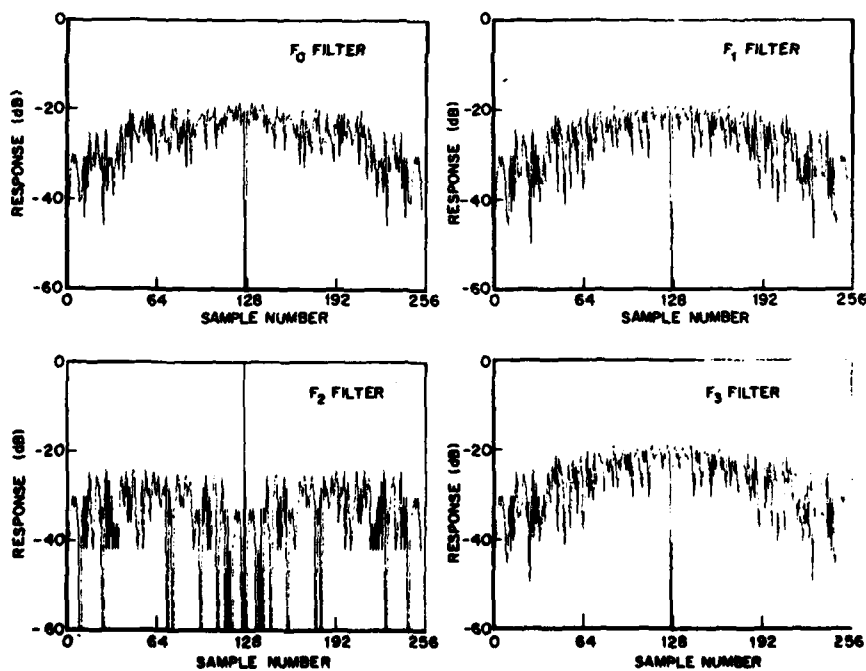

Fig. 3 — Responses of the doppler filters with an F_2-doppler target for the same
127-element-maximum-length binary code as in Fig. 1

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Table 1 — Mean-Squared Clutter Level Output from
Doppler-Steered Pulse Compressors

Waveform	Mean-Squared Clutter Level (dB)			
	F_0	F_1	F_2	F_3
13-Element Barker code	0.471	0.164	0.087	0.260
15-Element-maximum-length binary code*				
$(23_8, 1)^\dagger$	1.501	0.482	-0.119	0.217
31-Element-maximum-length binary code				
$(45_8, 20)^\ddagger$	1.103	0.135	-0.058	-0.029
$(45_8, 4)^\dagger$	1.379	0.143	-0.059	0.099
63-Element-maximum-length binary code				
$(103_8, 31)^\dagger$	1.186	0.103	0.168	0.008
127-Element-maximum-length binary code				
$(211_8, 39)^\ddagger$	0.875	-0.138	-0.099	0.131
$(217_8, 127)^\dagger$	1.211	0.088	0.172	0.225
$(203_8, 64)$	1.385	-0.516	0.143	0.122
$(203_8, 1)$	1.494	-0.510	0.093	0.207

*The maximum length binary codes are represented by (α_8, β), where α is the coefficient of primitive polynomial in octal notation and β is the initial condition in binary notation.
†Code with the lowest peak sidelobe.
‡Code with the lowest RMS sidelobe.

Note: The initial conditions derived for those codes wth either the lowest peak sidelobes or the lowest RMS sidelobes are different from those obtained by Taylor and MacArthur [3].

MTI DELAY-LINE CANCELERS

To eliminate the excess clutter, two or more successive echoes from each doppler passband must be subtracted in an MTI (Fig. 4). This prevents the system from parameter estimation with a single pulse. The delay-line canceler acts as a filter which not only rejects the *DC* component but also eliminates any moving target whose doppler frequency is the same as the pulse-repetition frequency (PRF) or an integer multiple therof. This gives rise to a blind-speed problem as in a conventional MTI radar.

RANGE-DOPPLER-COUPLED WAVEFORM SYSTEM

When at least two pulses are dedicated to the MTI, it is no longer necessary to employ waveforms with thumbtack ambiguity diagrams for accurate parameter estimation. For example, a variation of an MTI technique that takes advantage of the range-doppler-coupling effect could be used. This effect causes the range of the echo to vary with doppler frequency in a direction depending on the target velocity and the direction of the radar frequency sweep. By alternating the radar-frequency-sweep direction on successive transmissions, a moving target will appear at different ranges on successive pulses, while a stationary target will appear at same range. The echo from one pulse subtracted coherently or noncoherently from the echo of the next pulse (Fig. 5) will effectively cancel the nonmoving-target response but not the moving-target response. In this type of MTI, true range and velocity of the moving target can be estimated from the output. In addition, blind-speed problems are also eliminated except at zero doppler, where the blind speed is desired. It is emphasized that the implementation of the scheme shown in Fig. 5 does not require any doppler-steered pulse compressor and that only one delay-line canceler is needed.

The relatively doppler-tolerant low-sidelobe polyphase-coded waveforms [5-7] are particularly suitable for range-doppler-coupled-MTI applications. Some of these codes could become palindromic with
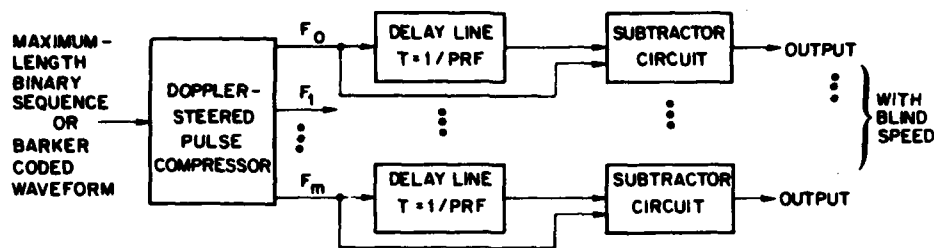
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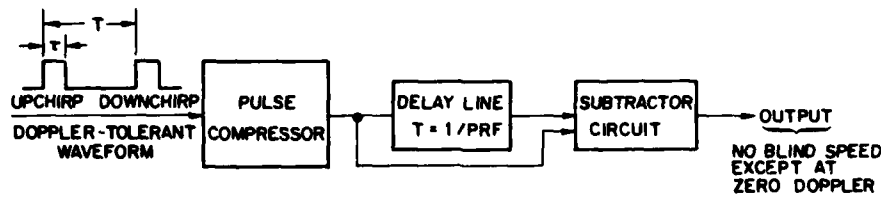Fig. 4 — Regular delay-line canceler, with no range-doppler coupling

Fig. 5 — Range-doppler-coupled MTI

real autocorrelation functions by slightly modifying the existing waveforms. For example, the PP4 code was obtained from the P4 code by taking the first sample of the waveform half a code-element duration after the leading edge while still sampling at the Nyquist rate. The frequency response of the single-delay-line canceler in a range-doppler-coupled MTI employing a PP4-coded waveform is shown in Fig. 6. It is evident that blind-speed problems do not occur except at zero doppler.
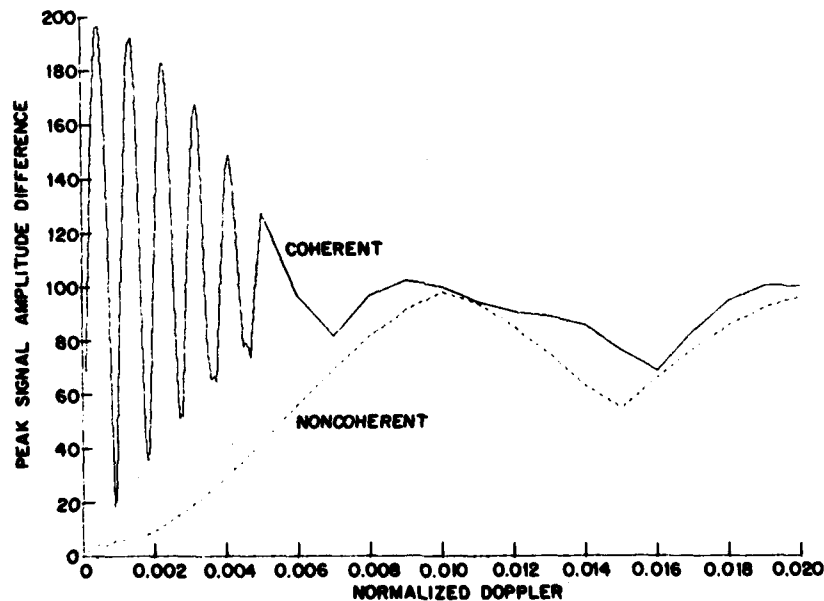

Fig. 6 — Frequency response of a two-pulse range-doppler-coupled MTI
using a PP4 code

In the event of nonmoving distributed clutter, simulation of a range-doppler-coupled MTI output for those palindromic codes showed that the returns canceled perfectly and that no clutter residue was obtained. It was demonstrated in the simulation that if there were moving targets in addition to the nonmoving distributed clutter, only the target responses were presented at the MTI output. As an

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example, Figs. 7 and 8 show the responses of a target with doppler frequency 0.01B, where B is the radar bandwidth. Figure 7 shows that the target is embedded in the clutter before cancellation, and Fig. 8 shows that the target is visible after cancellation using the PP4-coded waveform. The pulse-compression ratio was 100 in this case. At the MTI input, the clutter-to-target power ratio was 20 dB. At the MTI output, the oppositely range-doppler-coupled target responses were separated by two range cells and were resolved in range. The separation of these two target responses indicates that the target velocity and the true target range lies halfway between the two responses. Consequently, parameter estimation and subclutter visibility can both be accomplished by implementing such a range-doppler-coupled MTI with a palindromic polyphase-coded waveform.
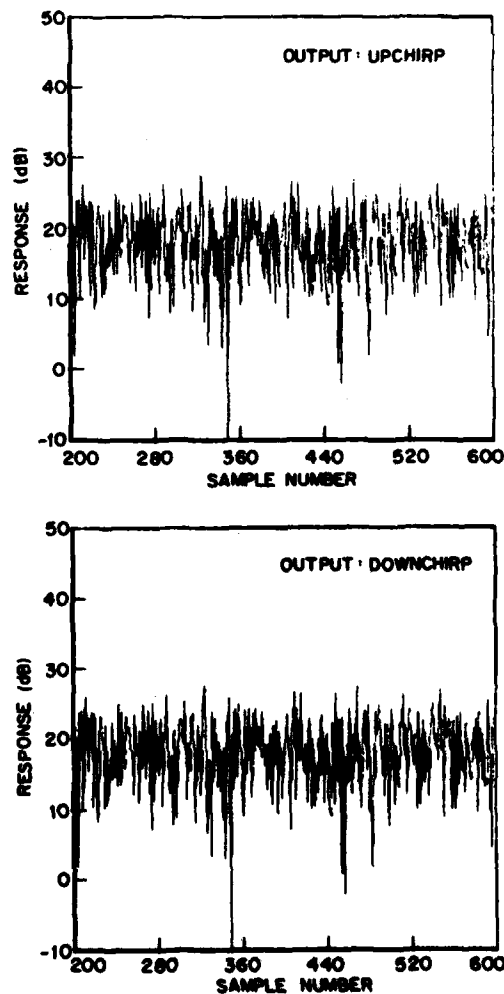

Fig. 7 — Responses of a pulse compressor before cancellation by a single-delay-line canceler
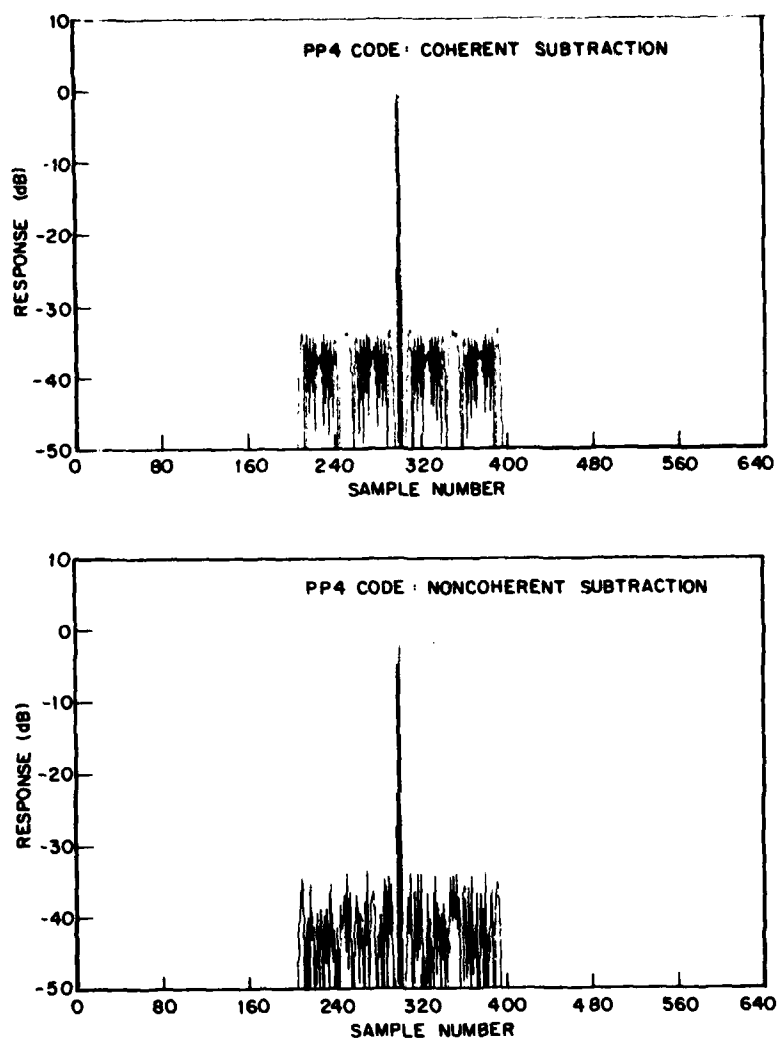
Fig. 8 — MTI output after cancellation by a single-delay-line canceler

CONCLUSIONS

It is demonstrated in the simulation that doppler resolution and clutter attenuation are not simultaneously available from doppler-steered pulse compressors using waveforms with thumbtack ambiguity diagrams in a nonmoving-distributed-clutter environment. As a consequence the implementation of a matched filter bank does not provide the capability of parameter estimation in a clutter environment. Subsequent conventional MTI processing at each filter output port can eliminate excess clutter with more than one transmitted pulse but has blind-speed problems.

In an MTI system, if the waveform with a thumbtack ambiguity diagram is replaced with one that range-doppler couples and is palindromic, both parameter estimation and subclutter visibility can be obtained without implementation of any matched filter bank.

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REFERENCES

1. C.E. Cook and M. Bernfeld, *Radar Signals: An Introduction to Theory and Applications,* Academic Press, 1967.

2. E. Brookner, *Radar Technology,* Chap. 8, Artech House, 1978.

3. S.A. Taylor and J.L. MacArthur, "Digital Pulse Compression Radar Receiver," APL Tech. Digest **6** (No. 4), 2-10 (1967).

4. F.E. Nathanson, *Radar Design Principles,* McGraw-Hill, 1969.

5. B.L. Lewis and F.F. Kretschmer, Jr., "A New Class of Polyphase Pulse Compression Codes and Techniques," IEEE Trans. Aerospace and Electronic Systems **AES-17**, 364 (May 1981).

6. B.L. Lewis and F.F. Kretschmer, Jr., "Linear Frequency Modulation Derived Polyphase Pulse Compression Codes," IEEE Trans. Aerospace and Electronic Systems **AES-18**, 637 (Sept. 1982).

7. F.F. Kretschmer, Jr., and B.L. Lewis, "Polyphase Pulse-Compression Waveforms," NRL Report 8540, Jan. 1982.